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Behaviour of kenaf fibre reinforced composite

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Abstract. This study presents the comparison on behavior of kenaf fibre composite and normal concrete. Use of natural fibre in construction industry is of tremendously interest in the past few decades. This study focus on investigate the material characteristic and the structural behavior of kenaf fibre composite compare with normal concrete. The percentages of kenaf fibre composite were calculated depend on the weight of concrete. Experimental investigation and comparison on behaviour such as compression test, splitting tensile test, slump test, water absorption test and 4 point loading beam test were discussed in this study. These studies found that kenaf fibre composite have better behaviour than normal concrete. Kenaf fibre composite has higher load capacity as compare with normal concrete. Moreover, these show that kenaf fibre composite are capable to behave better than normal concrete in all aspect when act as structural member.

1. Introduction

In the recent time, natural fibres have become increasingly popular in construction industry. This is because of its benefits such as renewability, low density, and high specific strength [1]. Natural fibres such as coconut fibres (coir), sugarcane bagasse fibres, bamboo fibres, and kenaf fibres, are introduced to the construction industry to use as the replacement of the traditional reinforce fibre for concrete. Traditional reinforce fibres such as glass fibres, steel fibres, and carbon fibres have add in great mechanical properties to the concrete, but these fibres will also causing some environmental issue due to their non-degradability. Besides that, these fibres are relatively expensive when compare with the natural fibres.

Among the natural fibres mention above, kenaf fibre has been give an account of possess great tensile and flexural strength [2]. Tensile and flexural strength of the fibre are key criteria to take into consideration if the fibre is planning to be used as reinforced fibre in concrete. The excellent properties of kenaf fibre result in a new concrete technology "kenaf fibre reinforced concrete". As literally, kenaf fibre reinforced concrete is the concrete that reinforce by kenaf fibre. Natural fibre composites generally have high specific strength, biodegradability, and low density [3]. According to Nishino [4], the mechanical strength and thermal properties of kenaf composites are higher than other natural fibre composites. Hence, kenaf fibre is more suitable to be used as reinforce fibre to the concrete as compare with other natural fibres. Moreover, kenaf is relatively commercially available and economically efficient among other natural fibre reinforcing material [5].

Natural fibre as reinforcement in concrete to replace the traditional reinforces fibre is of tremendous interest as natural fibre offer a more economical and environmental friendly in enhancing "green" building. "Green" building has received huge attention as the environmental issues are become more seriously in recent decade. Construction industry is playing an important role in this issue as the construction industry is one of the majors' contributors to the environmental issues. Construction industry has been using steel bars and synthetic fibres to reinforce the structure concrete. Huge amount of energy is required to produce steel bar and lots of pollutants are release during the process of producing energy and steel bars. The synthetic fibres will also induce some environmental issues due to their non-degradability.

Due to the disadvantages of the steel bars and synthetic fibres, natural fibres have become the alternative material for the construction industry. The use of natural fibres will reduce the application of steel bars and synthetic fibres. Hence, it is reducing the impact of construction industry toward environment.

From the past research, kenaf fibre is seen to be better than other natural fibres. The tensile strength of kenaf fibre has revealed to be 930MPa, which is higher than other natural fibres [6]. Kenaf fibre is capable to improve the structural properties. However, study of kenaf fibre combined with concrete has yet been published. Hence, it is necessary to investigate the hidden benefits of kenaf fibre composite so as to improve the properties of kenaf fibre composite. As we all know, the concrete is generally good in compression, but weak in tension. Therefore, the present research intended to study the shear behaviour of kenaf fibre composite and investigate the differences between normal concrete and kenaf fibre reinforced concrete.

The application of kenaf fibre composite can bring many benefits to the society. First and foremost, kenaf fibre composite can reduce the huge cost of using conventional building material. Kenaf fibre is relatively cheaper as compare to the conventional building material such as steel bars and synthetic fibres. The use of kenaf fibre can enhance the tensile strength of the concrete which will reduce the amount of steel bars require to reinforce the structure. Besides that, kenaf fibre will also replace the synthetic fibres as reinforce fibre in concrete. Hence, this will result in a lower cost of construction in term of materials. Lower cost of construction means the property can be retail at lower price.

The application of kenaf fibre (natural fibre) will replace the synthetic fibres. Synthetic fibres will cause some environmental issues due to their non-degradability. Moreover, some synthetic fibres are produced from non-renewable resource such as iron. In the other hand, kenaf fibre is renewable and biodegradable. Moreover, the planting of the kenaf fibre will also provide jobs for people. Overall, the result is a cleaner, healthier and better living environment for mankind.

In this research, the testing of the kenaf fibre composite will be carried out to investigate the kenaf fibre composite by adding 0.40% and 0.45% of kenaf fibre to act as structure member. The testing of the normal concrete will also carry out concurrently. This is to compare the behaviour of the kenaf fibre composite with normal concrete. Kenaf fibre composite and normal concrete will be cast into cube size and cylinder size. Compression test and tensile splitting test will be carried out to test the concrete cube and cylinder. An initial study on mix proportion of kenaf fibre composite will be conduct to gain the desirable characteristic strength. At the same time, the normal concrete with target strength of 30 MPa is design. All concrete specimens will go through the water curing session to optimise the properties of the specimens. Meanwhile, few cube specimens will be cast to perform the cube test to determine the compressive strength achieved. The concrete compression machine will be used to carry out this testing.

2. Methodology

This chapter was focused on the method and procedure to carry out this research. The materials used in this research also expounded. The trial mix proportion to obtain desire concrete strength was to be investigated. The dimension of the concrete cubes and cylinders were verified as well. Slump test, compression test, tensile splitting test, water absorption tests and beam test were carried out to fulfil the research objectives.

2.1. Materials

The basic materials used to produce the concrete include Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, Kenaf fibre and water.

2.2. Kenaf Fibre

Raw kenaf fibre were cut into 5cm length and treat chemically. The purpose of making kenaf fibre into 5 cm length was for ease of mixing and dispersion. Kenaf fibre were treated with 0.1 mol of aqueous sodium hydroxide (NaOH) which was produced by dissolve of 40 gm of NaOH in 1 L of distilled water for 2 hours. The purpose of this treatment is to remove any impurities on the kenaf fibre and chemically modify the surface of kenaf fibre. The volume of fibre added in the composite are 0.40% and 0.45% by weight of concrete. The sample pictures of kenaf fibre in 5cm and kenaf fibre under treatment of 0.1mol of NaOH solution are show in Figure 1 and Figure 2.

Figure 1. Kenaf fibre in 5cm length.

Figure 2. Kenaf fibre under treatment of 0.1mol of NaOH solution.

2.3. Initial mixture proportion

In order to achieve the optimum strength of the concrete, trials are conducted on the mixing proportion by varying the amount of the materials such as water to cement ratio (w/c), cement, water, sand and aggregate. Tables 1 show the mixing proportion used in the beginning to obtain the optimum concrete strength for normal concrete (NC) and kenaf fibre Composite (KFC).

Table 1. Initial mixture proportion.

Name	w/c	Cement (kg/m^3)	Water (kg/m^3)	Fine Aggregate <2.36mm	Fine Aggregate <4.5mm	Coarse Aggregate <10mm	Coarse Aggregate <20mm
NC	0.47	340	160	258	258	460	925
0.40% KFC	0.47	340	160	258	258	460	925
0.45% KFC	047	340	160	258	258	460	925

2.4. Mixing procedure

The procedure of making and curing of concrete done in this research is fully complies with ASTM C 192 [7]. Mixing procedure is a critical criterion to produce an effective mixing and obtain a trustworthy result. Procedure and duration of mixing is essential to develop a homogenous mix. Different mixing proportion has different duration of mixing. It is very important to take into account of the usage of chemical admixture, water-to-cement ratio and sequence.

First of all, measure the weight of each material to ensure the mix proportion is follow. After that, all materials will put into concrete mixer for mixing. The coarsest material will pour into the concrete mixer first and the finest material will pour into concrete mixer lastly. The sequence will be coarse

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aggregate, fine aggregate, OPC, and kenaf fibre. After these materials are mixes together in concrete mixer, weighted water is pour into concrete mixer to mix together with the materials mention above.

2.5. Casting and curing
Casting procedure will be following the ASTM C 31[8] standard. Free water will be maintained on the surface of specimen during curing. Concrete cubes, cylinders and beams will be cure in water tank for 7 days and 28 days.

2.6. Compression test
Concrete compression test is performed in fully complies with ASTM C 109 [9]. The purpose of this test is to study the effect of kenaf fibre on the compressive strength of concrete. Concrete compressive strength at 7 days and 28 days will be recorded for both normal reinforced concrete and kenaf fibre reinforced concrete. The cube mould with 100mm x 100mm x 100mm dimension is used.
Concrete cube will be placed in the compression machine and apply increasing load on it until failure. The maximum load applied before concrete cube reach failure is recorded for both normal reinforced concrete and kenaf fibre reinforced concrete.

2.7. Tensile splitting test
Concrete cylinder specimens will be used to perform tensile splitting test as complies with ASTM C 496 [10]. The purpose of this test is to study the effect of kenaf fibre on the tensile strength of concrete. Concrete tensile strength at 7 days and 28 days will be recorded for both normal reinforced concrete and kenaf fibre reinforced concrete.
Concrete cylinder specimens will be placed in equipment before place into compression machine and apply increasing load on it until failure. The maximum load applied before concrete cylinder reach failure is recorded for both normal reinforced concrete and kenaf fibre reinforced concrete.

2.8. Water absorption test
Water absorption test of concrete is performed as complies with ASTM C 1585[11]. The purpose to carry out water absorption test is to investigate the rate of absorption or sorptivity of the water by hydraulic cement concrete.

2.9. The 4-point loading beam test
For the concrete beam samples, two beams of kenaf fibre reinforced concrete with different kenaf fibre contents and one control sample with normal weight concrete (NWC) would be required. In order to obtain a more accurate result of the kenaf fibre reinforced lightweight concrete, 3 similar samples of the same kenaf fibre content would be needed. Thus, a total of 9 samples would be required. All the beams were subjected to a modify 4-point loading test. The beam's reinforcements and beams are shown in the figures 3 and 4 below.

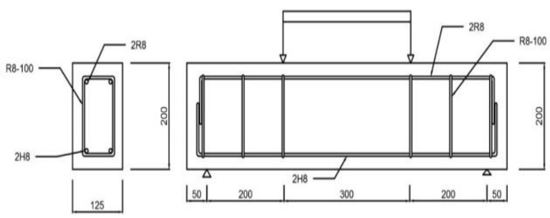

Figure 3. Reinforcement layout of beam sample.

Figure 4. Concrete beam produced.

3. Results and discussion
This chapter present the data obtained from series of testing and discussion on the data and other observation from testing.

3.1. Specimens properties and observation

Table 2 shows the 7 days and 28 days compressive strength of normal concrete (NC) and kenaf fibre composite (KFC).

Table 2. 7 and 28 days compressive strength.

Reference Name	7-day Strength (N/mm^2)	Average 7-day Strength (N/mm^2)	28-day Strength (N/mm^2)	Average 28-day (N/mm^2)
0.4% KFC	25.23 23.56 24.68	24.49	32.64 31.98 33.41	32.68
0.45% KFC	23.12 20.97 22.45	22.18	33.68 31.46 31.70	32.28
NC	22.85 24.32 23.90	23.69	32.56 34.85 34.11	33.84

Table 2 shows that kenaf fibre composites have gained higher 7 days strength than normal concrete but the 28 days strength is similar. The normal concrete has followed the typical strength-gain curve which shows that the 7 days strength is around 65% of 28 days strength. However, kenaf fibres composite does not exatly follow the typical strength-gain curve. The 7 days strength of kenaf fibre composite is varies from 70% to 75% of 28 days strength. Besides that, crack pattern of the concrete cube of normal concrete and kenaf fibre composite is also different. Concrete cube of normal concrete has many large cracks develop on it and also more fragment. On the other hand, concrete cube of kenaf fibre composite behave oppositely with concrete cube of normal concrete. Figure 5 and Figure 6 show the concrete cube of normal concrete and kenaf fibre composite after compression test. Table 3 shows the 7 days and 28 days tensile splitting strength of normal concrete and kenaf fibre composite.

Figure 5. Concrete cube of normal concrete after compression test.

Figure 6. Concrete cube of kenaf fibre composite after compression test.

Table 3 shows that the 7 days and 28 days tensile splitting strength of normal concrete is lower than kenaf fibre composite. Besides that, splitting crack of normal concrete also appears to be larger than kenaf fibre composite. This is because of the kenaf fibre help the concrete to withstand the tensile splitting force by holding the concrete together. Kenaf fibre will fail to hold the concrete together after the tensile splitting force exceeds the kenaf fibre tensile strength. Figure 7 and Figure 8 show the kenaf fibre inside concrete cylinder specimen and the splitting crack of the kenaf fibre composite cylinder specimen. Table 4 shows the 7 days and 28 days density of normal concrete and kenaf fibre composite.

Table 4 shows that both kenaf fibre composites density are lower than the normal concrete density. This is because of the kenaf fibre occupy a space in the concrete. Density of the concrete can be greatly affected by the total quantity of cement and aggregate. When kenaf fibre is added, it will cause less aggregate contain in the concrete. Moreover, kenaf fibre has a lower density than aggregate. Hence, the density of the kenaf fibre composite will be lower than normal concrete. Table 5 show the water absorption of normal concrete and kenaf fibre composite.

Table 3. 7 days and 28 days tensile splitting strength.

Reference Name	7-days Strength (N/mm^2)	Average 7-days Strength (N/mm^2)	28-days Strength (N/mm^2)	Average 28-days Strength (N/mm^2)
NC	1.59	1.55	1.98	2.07
	1.55		2.12	
	1.52		2.10	
0.4% KFC	2.23	2.37	3.56	3.58
	2.50		3.49	
	2.38		3.69	
0.45% KFC	2.14	2.13	3.16	3.28
	2.10		3.21	
	2.15		3.47	

Figure 7. Kenaf fibre inside concrete cylinder specimen.

Figure 8. Kenaf fibre composite cylinder specimen.

Table 4. 7 days and 28 days density.

Reference Name	7-day Density (kg/m^3)	Average 7-day Density (kg/m^3)	28-day Density (kg/m^3)	Average 28-day Density (kg/m^3)
NC	2500	2427	2530	2447
	2380		2390	
	2400		2420	
0.4% KFC	2360	2340	2350	2335
	2320		2336	
	2340		2320	
0.45% KFC	2260	2260	2340	2320
	2300		2360	
	2220		2260	

Table 5 shows that both kenaf fibre composites have absorb more water than normal concrete. Moreover, water absorption increase as the kenaf fibre contains increase. According to Tope Moses [2], the increased water absorption may be attributed to the increase in void and pore with the inclusion of kenaf fiber in the concrete. Hence, as the kenaf fibre increase, more void and pore are present in the concrete. Besides that, kenaf fibre also has higher water absorbability. Table 6 shows the slump value for normal concrete and kenaf fibre composite.

Table 5. Water absorption test.

Reference Name	Water Absorption (g)	Average Water Absorption (g)	Water Absorption (%)	Average Water Absorption (%)
NC	60	73	2.61	3.18
	80		3.42	
	80		3.51	
0.4% KFC	100	90	4.42	4.01
	90		3.60	
	80		4.01	
0.45% KFC	120	130	5.31	5.82
	120		5.31	
	150		6.85	

Table 6. Slump value.

Reference Name	Slump Value (cm)
NC	15.5
0.40% KFC	5.3
0.45% KFC	5

Table 6 shows that the slump value of kenaf fibre composite is much smaller than normal concrete. Slump value is one of the indicators for the workability of concrete mixture. The higher the slump value, the better the workability of the concrete mixture. The reduction of slump value in kenaf fibre composite may cause by the high water absorbability of kenaf fibre. Because of most water was absorbed by the kenaf fibre, less water are remain for the concrete mixture. Hence, the slump value of kenaf fibre composite will be greatly reduced.

3.2. Structure test

Structure test will be carried out once the beam specimens reach the target compressive strength which is 30MPa, not matter whether the beam specimens has reach 28 days. The compressive strength will be determined by compression test of concrete cube cast by the same batch of concrete mixture. Theoretical design moment and experimental ultimate moment of the beam specimens is shows in Table 7.

Table 7. Moment comparison.

Reference Name	Theoretical Design Moment (kNm)	Ultimate Aplied Load (kN)	Experimental Ultimate Moment (kNm)	Capacity Ratio
NC	6.8	130	13	1.91
		130	13	1.91
		137	13.7	2.01
0.40% KFC	6.8	137	13.7	2.01
		138	13.8	2.03
		139	13.9	2.04
0.45% KFC	6.8	140	14	2.06
		142	14.2	2.09
		144	14.4	2.12

Table 7 shows that the experimental ultimate moment of normal concrete is 91%, 91% and 101% (average 94.33%) higher than theoretical design moment. For 0.45% KFC, the experimental ultimate moment is 106%, 109% and 112% (average 109%) higher than theoretical design moment. For 0.40% KFC, the experimental ultimate moment is 101%, 103% and 104% (average 102.67%) higher than theoretical design moment. Besides that, 0.45% KFC has taken the highest load among these proportions.

4. Conclusion

The required results are finally obtained after a series of laboratory works. The testing to investigate the physical properties of kenaf fibre is water absorption test. It was found out that the kenaf fibre composite will absorb more water than normal concrete. Besides that, as the kenaf fibre increase, the water absorb by the composite also increase. This is because of the increase in void and pore with the inclusion of kenaf fibre in concrete. Moreover, kenaf fibre also has higher water absorbability. Because of the reasons mention above,

The compressive strength of the kenaf fibre composites were determined to be 32.68 MPa and 33.84 MPa for 0.40% and 0.45% kenaf fibre composite respectively. The targeted compressive strength before the laboratory works were carried out is 30 MPa. The results obtained have fulfilled the targeted compressive strength. The result shows that all concretes are capable to take more load after exceed theoretical design moment. 0.45% KFC averagely takes 9.67kN more load than normal concrete before yielding.

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